TRAINING MODULES
–
CATHODE MODULE

INNOVATIVE COST IMPROVEMENTS
FOR BALANCE OF PLANT COMPONENTS
OF AUTOMOTIVE PEMFC SYSTEMS

INN·BALANCE
AUTOMOTIVE FUEL CELL

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1. PARTNERS ROLE

BROSE Fahrzeugteile GmbH & Co. KG

- Elaboration of the layout of the cathode module
- Selection and procurement of various components such as control valves and air filter
- Development of a dedicated simulation platform
- Assessment of final laboratory tests

Celeroton AG

- Assembling and testing of several prototypes of the turbo compressors
- Contribution to the design optimization

PowerCell Sweden AB and DLR e.V.

- Contribution to the design optimization

2. MAIN FUNCTIONS OF THE CATHODE MODULE

Prime function

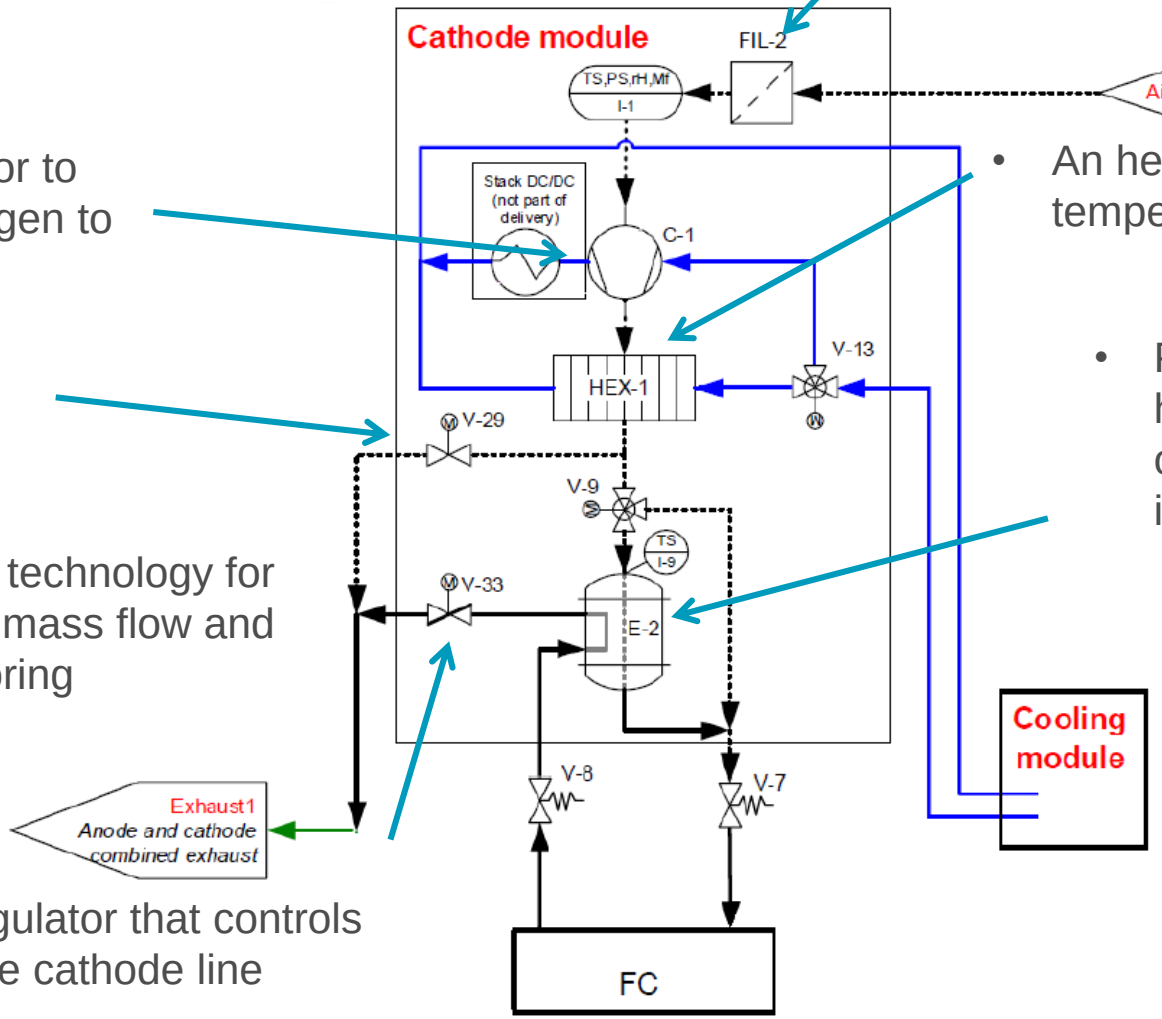
- Supply a desired mass flow of oxygen at a particular reference humidity to the FC stack. Oxygen will combine with electron and hydrogen ions released by the hydrogen fuel to form water that flows out of the stack. To ensure proper function, pressure, mass flow, temperature and humidity of the oxygen are constantly measured and controlled.

Secondary functions

- Effective air inlet filtration through an air filter to protect the sensitive cathode components and avoid that nitrous oxides or compounds with sulphur and ammonia enter the fuel cell
- Monitoring: sensors constantly measure and control the mass flow, humidity, temperature and pressure of the oxygen
- Humidity control: an humidifier maintains a proper water balance in the fuel cell system and guarantees optimized fuel cell performance
- Temperature control: an intercooler regulates the temperature and ensure that the temperature specifications are met at every operating point
- Efficient air compression: the turbo compressor is the core component of the cathode module. It must be characterized by low weight, high operating efficiency and compactness

3. ANODE MODULE COMPONENTS (WITH PASSIVE RECIRCULATION)

- An air filter to separate compounds that could damage the fuel cell
- A turbo compressor to compress the oxygen to the required level
- An heat exchanger to control the temperature of the inlet air
- Control valves
- Passive membrane humidifier to maintain an optimized water balance in the fuel cell system
- Necessary sensors technology for pressure, humidity, mass flow and temperature monitoring
- Connection to the thermal management system to cool the compressor and the compressed oxygen
- Back pressure regulator that controls the pressure of the cathode line



4. AN INNOVATIVE TURBO COMPRESSOR

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Advantages

- High speed electric compressors achieving speeds up to 1 millions revolutions per minute and allowing dynamic control of both pressure and mass flow
- The compressor has air bearing which compared to conventional oil bearing guarantees that the air supply remains pure and that pressure fluctuations are eliminated/reduced
- The aerodynamic design of the compressor was developed in such a way that the stack can be operated at its highest efficiency in all operating points while maintaining highest efficiency of the air turbo compressor

5. SPECIFIC CHALLENGES RELATED TO THE DESIGN PROCESS

Definition of the surge line of the air compressor and design of the associated electronics

- To control precisely the compressor and avoid the phenomenon of compressor surge (aerodynamic instability characterized by strong vibrations and oscillations that could lead to irreversible damage), the so-called “surge line” of the compressor has to be determined. Once determined, the control system will prevent the compressor from operating in a certain parameter area that may lead to a compressor surge.
- The design of the electronics for operating the turbo-compressor system represents a big challenge. The compressor must have a consistently high efficiency over a wide operating range from vehicle start to maximum fuel cell power.

Selection of the right components that have to meet fuel cell specifications

- One of the challenge to overcome was to find off-the-shelf solutions that fulfil specific fuel cell requirements (humidifier capable of operating at high flow rates and control valves without pressure drops). Requests were sent to several suppliers before finding the right components.

Compactness and compatibility with conventional manufacturing

- The cathode module must be of reduced weight and volume to allow for a better integration in the fuel cell system and vehicle powertrain. Furthermore, the design of the cathode module must be optimized in such a way to reduce the part count and the corresponding assembly time, thus mitigating the risk of pressure drops and make it more suitable for series production

6. MAIN DEVELOPMENT STEPS

Steps taken during the development of the anode module

1. Elaboration of a first layout of the cathode module by Brose in the form of a piping and instrumentation diagram. Celeroton, DLR and PowerCell actively contribute to this task
2. Assembling and testing of several prototypes of the turbo compressors by Celeroton
3. Selection and testing of various components (valve sensors, humidifier, heat exchanger) by Brose
4. Development and testing of the cathode control algorithm in a simulation environment. The software was implemented on hardware and used to run a laboratory test bench in which the cathode system is undergoing various performance tests. These actions were carried out by Brose
5. Improvement of the design and packaging size by Brose and Celeroton based on feedback from PowerCell and CEVT to make it suitable for series production (e.g. low pressure die casting selected as manufacturing process for the turbo compressor)
6. Integration of the cathode subsystem in a fuel cell system and software test alongside other subsystems of the fuel cell
7. Integration of the cathode subsystem into a prototype fuel cell vehicle from CEVT. The vehicle will undergo several tests corresponding to various driving conditions